A Structural Hierarchical Approach to Longitudinal Modeling of Effects of Air Pollution on Health Outcomes

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Abstract. In the paper we present the methodology of construction and interpretation of models for the study of air pollution effects on health outcomes and their applications. According to the main assumption of the model, every health outcome is an element of the multivariate hierarchical system and depends on the system meteorology, pollution, geophysical, socio-cultural and other factors. The given model is built on system approach using GEE-technique and time-series analysis. The model is tested by the data collected from lung function measurements of the group of 48 adults with vulnerable respiratory system in Leipzig, Germany, over the period from October 1990 till April 1991 (the total of 10,080 individual daily records). The meteorological variables comprise temperature and humidity, while the pollution variables are made of the Total Suspended Particulate Matter and Sulfur Dioxide airborne concentration. Results of the models, constructed separately for morning, noon, and evening, demonstrate direct and indirect influence of air pollution on the lung function under the certain meteorological, individual factors and seasonal changes.

1 Introduction

Influence of the environment on human health is a problem of fundamental magnitude deeply concerning all mankind. Year by year, this problem only becomes more acute one, painful and financially consuming. As a matter of fact, at stake is survival of human race. Majority of the studies on in this problem were concentrated on efforts to expose adverse effects of urban air pollution on health outcomes [6, 1, 8, and many others]. The adverse affects included enlarged mortality and morbidity rates, pulmonary function decrements, visits to emergency departments and hospital admissions, and increased medication use. The association between air pollution and the adverse effects revealed in these studies is mostly consistent, despite differences in definitions of exposure and outcome measurements and the statistical methods used to model the relationship between air pollution and health outcomes.

It is obvious nowadays that to analyze the above link one has to include multiple aspects into a statistical model, such as geophysical factors (periodical change in the seasons, geomagnetic field magnitude, sun radiation level, … ), meteorological factors (humidity, temperature, wind strength and direction, … ), socio-cultural factors (all-national cycles in life stile, for example: sequences of working days and weekends, holydays and regular days, … ), individual factors (genetic background, body mass index, smoking, physical fitness, … ), and others. But the question of principle is how to do it?

However, to construct more adequate model it is necessary to not just consider all the model factors mentioned above but also their hierarchical and other relationships
obtained from a-priori knowledge about the model. Such approach (based on structural hierarchical models and partially described in [3] and [2]) is certainly more adequate reflection of reality than previous one.

In this paper, basing on the techniques of generalized linear models (GLM), generalized estimation equations (GEE) [7, 4, 9], and time-series technique we build a longitudinal model of the structural hierarchical kind mentioned above.

A model of that kind does not have one but several complicatedly related functional patterns of independent variables. Therefore, any conventional epidemiologically sound interpretation of the model results becomes impossible. Explaining the model in epidemiologically meaningful terms we propose the interpretation we call "multi-layer" one. In the paper we develop the strategy and methodology of this interpretation.

To computerize employing of the structural hierarchical approach to longitudinal modeling we constructed and published the program module quickmodel_interact implemented as an ado-file of Stata statistical software (version 8.2, Stata Corp, 2003).

We applied the model on the data collected from lung function measurements of the group of 48 adults with vulnerable respiratory system in Leipzig, Germany, over the period from October 1990 till April 1991 (the total of 10,080 individual daily records).

2 Constructing the Model

2.1 Structural Hierarchical Model

Let us consider term "health" as an outcome of our major interest.

We assume that "health" is a factor of a multi-factor hierarchical system, which also includes meteorology, pollution and other factors (Figure 1).

![Hierarchical Structural Model of Relation between Health Outcome and Geophysical, Meteorological, Socio-Cultural, Pollution factors](image)